knowledge gaps & methodology

## **Problem statement**

The benefits for lightweighting of aircraft structures are abundantly clear. However, with materials such as high-performance alloys and polymer composites comes increased cradle-to-gate impacts and unappealing end-of-life solutions.

Strategies to increase circularity potential such as modular design and the use of recycled materials are unapealing if they result in an increase to aircraft mass. But does that always have to be the case?

>98% of aviation's impact on climate change is linked to the production and consumption of kerosene & therefore benefits directly from lightweighting

the aircraft structure itself, on the other hand, makes up much less

there's also this bit from the

construction of the airport

# Research question

What is the trade-off in impacts between circularity strategies for aircraft structures and the resulting mass-induced emissions?

# Methodology

A life cycle assessment (LCA) consists of several stages. The schematic on the right illustrates parts of the first two stages: goal & scope definition and the life cycle inventory (LCI). Already here, previous studies have left some gaps. The following stage is life cycle impact assessment (LCIA), where the high altitude of aviation emissions present us with a challenge.

#### LCI: quantifying emissions

The effect which mass changes have can be represented by pre-existing aviation models of fuel-flow and the resulting emissions (Quadros et al., 2022). However, using these models to this end in an LCA has rarely been done before.

short-term effects
of aviation also depend
on the time and place on the
globe of emissions — e.g.,
nighttime flights are thought to
have a larger net-warming
impact than flights during the
day (Lee et al., 2021)

CO, and SO<sub>x</sub> are to varying degrees responsible for air quality degredation due to tropospheric O<sub>x</sub> (ozone, summer smog) and PM<sub>2.5</sub> (fine particulate matter) — with serious consequences to human health (Grobler et al., 2019)

1500

CO<sub>2</sub> is an important greenhouse gas, but the location of aviation emissions means that, e.g., NO<sub>x</sub> and effects on cloudiness also contribute significantly to global warming

(Grobler et al., 2

SO<sub>x</sub>

soot

Cloudiness

viation emissions (Lee et al., 2021)

unburnt hydrocarbons (HC)

#### LCIA: non-CO2 effects

2000

Airports are often close to cities, but cruise altitudes are high above ground. This means conventional LCIA methods become less appropriate. Efforts have been made to determine representative impact factors, but there is still much uncertainty.

#### System boundary for LCA to be executed Aircraft cradle to gate Resource extraction Manufacturing Energy carrier life cycle Assembly Well to tank Resource Aircraft in use extraction **Operations** Production Tank to wake Distribution **Storage → Consumption** Servicing Airport infrastructure life cycle Aircraft end of life Legend: Activity based on Activity based on Activity left out foreground data background data of scope

Based on Cox et al., 2018

### **Energy carriers**

Major transitions in the in-use energy sources for aviation would mean that other aspects of the life cycle will become more important. Such potential future changes will be taken into account through a number of scenarios.

### Component case studies

The focus is on opportunities where mass changes between components are minor,

understood, as (1) manufacturing impacts are often simplified to extremes and (2) it is clear that large changes in mass affect in-use energy consumption in a way that cannot be made up for in other life cycle stages.

## References

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